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The usefulness of ultrasound and the posterior fat pad sign in pulled elbow

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ABSTRACT

Introduction: A pulled elbow is a common cause of acute elbow pain that is generally managed by a reduction maneuver without radiographic examination. However, children with atypical presentation with no history of abrupt longitudinal traction should undergo elbow imaging. This study aimed to investigate plain radiography findings and determine the usefulness of ultrasonography (US) in atypical pulled elbow.

Materials and methods: We retrospectively reviewed the medical records and images of 37 (22 males) consecutive patients with pulled elbow who presented with an atypical history or failed reduction between April 2015 and September 2018. Mean age at presentation was 4.34 years (range, 1.25–9.5 years). Of the 37 elbows, 20 were left elbows. The injury mechanism, incidence of the posterior fat pad sign on plain radiographs, and characteristic US findings, pre- and post- reduction, were investigated.

Results: The original mechanisms of injury included slipping (n = 14), rolling over the arm (n = 7), vague history (n = 6), falling down (n = 6), abrupt longitudinal traction (n = 2), and direct injury (n = 2). On plain radiographs, six of the 37 elbows (16%) showed the posterior fat pad sign. Before the reduction, an entrapped supinator, a pathognomonic sign of pulled elbow, was identified on US in all cases. After reduction, the characteristic US findings showed a disentangled and swollen supinator (100%) and restored annular ligament (100%) in all successful cases. Although a click was not felt in three cases, the reductions were considered successful because the annular ligament was restored on US with free elbow motion.

Conclusion: Pulled elbow may be caused by atypical mechanisms of injury, such as slipping and rolling over the arm. Clinicians should be aware of the possibility of the posterior fat pad sign on plain radiographs of pulled elbow to prevent unnecessary immobilization. In such circumstances, US is a useful method for detecting an entrapped supinator and confirming adequate reduction via restoration of the annular ligament in children with atypical pulled elbow.

Introduction

Pulled elbow is frequently encountered in young children, and it is typically caused by a sudden pull on the forearm and interposition of the torn annular ligament between the radiocapitellar joint [1]. Children with a pulled elbow usually avoid using their arm and hold the elbow mildly flexed and the forearm in the prone position, unwilling to supinate the arm [2]. If a child presents with arm pain with a history of a pull on the arm, it is considered a typical pulled elbow and generally managed by a reduction maneuver without radiographic examination [3].

However, in children with elbow pain without the typical history of abrupt longitudinal traction, considered an atypical pulled elbow [4], or with unusual presentation of failed symptomatic relief after repeated reduction attempts, elbow imaging for differential diagnosis should be performed prior to any further reduction attempts. Ultrasonography (US) has been proposed as a reliable tool to reveal several characteristic findings of pulled elbow [5–8]. However, there is a concern that US examination and interpretation depends on the technical skill of the operator [4,9]. Furthermore, although the plain radiographic findings of pulled elbow are known to appear normal, our clinical experience has shown that the posterior fat pad sign occurs in

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some children with pulled elbow. Therefore, the purpose of this study was to investigate the findings of plain radiographs and determine the usefulness of US in children with atypical pulled elbow.

Materials and methods

Patients

This was a retrospective study that was approved by the Institutional Review Board of our hospital, which is a tertiary referral hospital. We retrospectively reviewed the medical records and images of 37 (22 males) consecutive patients with pulled elbow who presented with an atypical history or failed reduction between April 2015 and September 2018. The mean age at presentation was 4.34 years (range, 1.25–9.5 years). Of the 37 elbows, 20 were left elbows.

Evaluation of the posterior fat pad sign

Posterior fat pad sign was measured by comparison with the contralateral side lateral radiographs taken with the elbow flexed. The plain radiographs were rendered anonymous by removing names, identity numbers, and dates, as well as any other references. Two independent investigators (WY.J. and DH.K.) reviewed the posterior fat pad sign on plain radiographs. Intra-observer reliability was checked by repeated measurements of the radiographs of the study cases with a four-week interval. Interobserver reliability was calculated using the first session of measurements from the two observers.

US protocol for pulled elbow

The child was seated opposite the ultrasound operator. US was first performed on the unaffected elbow as the control rather than the affected elbow. US examination was performed using the 7.5 MHz linear US transducer, and the Aplio 500 Platinum Series (Toshiba Medical Systems Co, Otawara, Tochigi, Japan) real-time US machine was used. The elbow was extended as far as the children could tolerate, and a probe was used to locate the anterior portion of the radiocapitellar joint longitudinally (Fig. 1). When the radiocapitellar joint was noted clearly, we recorded: (1) whether there was a change in the shape of the supinator muscle, (2) whether the annular ligament was in place, (3) whether there was an enlargement of the synovial fringe, and (4) whether there was effusion in the coronoid and olecranon fossae (Fig. 2). After the diagnosis of pulled elbow was confirmed, a reduction maneuver was performed. If a click was felt during the reduction maneuver, it was considered a successful reduction, and the children were observed as they voluntarily used their arm. After 10 min, US was performed again on the affected elbow to compare the ultrasound images between pre- and post-reduction. When a click was not felt, reduction was performed twice at an interval of 5 min, after which US was performed again 10 min later. If the symptom was not relieved or US findings of reduced pulled elbow were not found even after the repeated reduction trial, the elbow was immobilized by applying a long-arm splint and the patient was followed-up several days later. If the symptom persisted at follow-up, the same procedure and US were repeated. The incidence of the characteristic US findings, pre- and post-reduction, was investigated.

Statistical analysis

We measured the width of the supinator on US images, calculated the ratio of the width between the affected supinator and unaffected supinator of the contralateral side, and used the ratio to compensate for the individual variability of the size of the supinator in growing children (Fig. 2). The Pearson correlation coefficient was used to analyze the relationship between supinator swelling and the 'time to reduction' and 'number of reduction attempts'. The Student *t*-test was used to compare the ratio of the width between the affected supinator and unaffected supinator on the contralateral side, which followed a normal distribution.

Fig. 1. Ultrasonography examination is performed at the anterior portion of the radiocapitellar joint longitudinally.

Results

All patients received treatment at another hospital or additional management in the emergency department of our hospital before visiting the outpatient department. Nine patients were referred with a diagnosis of occult fracture, 10 patients were referred for unimproved contusion, and 18 patients had undergone a reduction maneuver without symptomatic improvement. Among 18 patients who experienced prior failed reduction attempts, 17 had undergone one attempt and one had undergone three attempts before presenting to our center. The original mechanisms of injury included slipping (n = 14), rolling over the arm (n = 7), vague history (n = 6), falling down (n = 6), abrupt longitudinal traction (n = 2), and direct injury (n = 2). The average duration of symptoms before the visit was 3 days (range, 0–7 days).

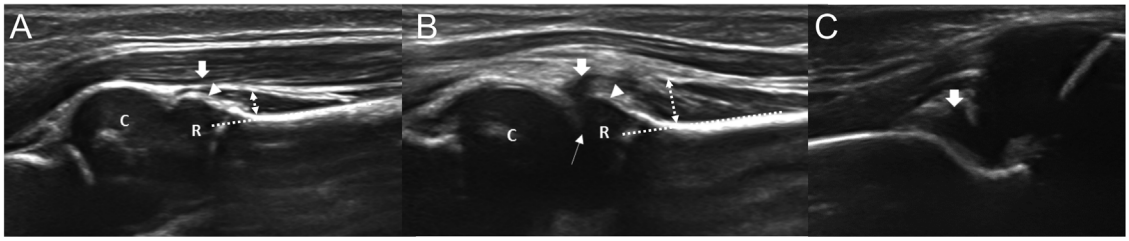

Fig. 2. Ultrasonography shows the supinator muscle with a sharp edge (arrow) and the annular ligament (arrow head) on the unaffected side (A). In pulled elbow, ultrasonography before reduction (B) shows an entrapped supinator muscle in the radiocapitellar joint (bold arrow), absent annular ligament (arrow head), and an enlarged synovial fringe deep to the radiocapitellar joint (arrow) and olecranon fossa effusion (C). The degree of swelling of the supinator was evaluated by comparing the width of the supinator muscle (dash line) at the radial neck area between the unaffected side (A) and affected side (B). C: capitellum, R: radial head.

Intraobserver and interobserver agreement for the detection of the posterior fat pad sign showed almost perfect agreement according to the Landis and Koch kappa values [10] ($\kappa = 0.939$ and $\kappa = 0.942$, respectively). In six of the 37 elbows (16%), the posterior fat pad sign was identified on plain radiographs.

The abnormal US findings of the pulled elbow differed from the unaffected side with the following incidences: an entrapped supinator (100%), absent annular ligament (uncovered cartilage sign, 74%), coronoid or olecranon fossa effusion (100%), and deep synovial fringe (63%). After reduction, the characteristic US findings showed a disentangled and swollen supinator (100%), restored annular ligament (100%), subsupinator effusion (58%), and retrieved synovial fringe (58%) (Fig. 3).

The mean 'time to reduction' at our outpatient department was 3 days (range: 1–12 days) after the occurrence of elbow pain. There was no significant relationship between the supinator swelling and the 'time to reduction' ($r=-0.05$, $p = 0.79$) or 'number of reduction attempts' ($r = 0.02$, $p = 0.92$). There was no significant difference in the supinator swelling between patients with failed reduction attempts prior to visiting our outpatient department and the remaining patients (0.33 ± 0.15 vs. 0.34 ± 0.17, $p = 0.76$).

Successful reduction was accomplished on the first attempt in 28 (74%) of the 37 patients. Three patients achieved successful reduction after two to three attempts on the same day, and two patients underwent another reduction maneuver three days later due to failed reduction. The remaining four patients underwent closed reduction under general anesthesia in the operating room due to an irreducible pulled elbow; two cases involved three failed reduction attempts within three days, one case involved four failed reduction attempts within four days, and the remaining case involved four failed reduction attempts within seven days.

Discussion

Pulled elbow is a common injury of early childhood. Since a young child's bones and muscles are still developing, it typically takes only a mild force to pull the bones of the elbow partially out of place, making pulled elbow a very common occurrence. Therefore, pulled elbow occurs most often in children aged 1–4 years, though it can occur during adolescence [11]. In the present study, the mean age of the included subjects was 4.34 years (range, 1.25–9.5 years), which is older than that in previous reports [5,7,12] on typical pulled elbow. A possible explanation is that all patients in this study were referred cases due to atypical presentations of pulled elbow. In this study, many pulled elbow cases presented with a history of slipping, rolling over the arm, or vague circumstances. If such cases are incorrectly diagnosed as occult fractures based on the injury mechanism inferred by the history, the pulled elbow may be immobilized unnecessarily. In this study, US demonstrated usefulness in detecting pulled elbow and confirming adequate reduction in children with atypical presentations.

The pathology behind pulled elbow has been debated for decades. Choung and Heinrich [13] stated that pulled elbow is caused by radial head subluxation. For these reasons, many authors [7,14] sought to measure the widened radiocapitellar distance of the affected elbow and compare it to that of the unaffected elbow for the diagnosis of pulled elbow. However, the mean difference was approximately 2 mm, and such a small difference resulted in low sensitivity for the detection of pulled elbow. Recent biomechanical studies have found that pulled elbow most likely results from the entrapment of the annular ligament between the subluxed radial head and the radiocapitellar joint [8]. Furthermore, entrapment of the anterior part of annular ligament between the subluxed radial head and the radiocapitellar joint has been confirmed in magnetic resonance imaging studies [4,15] as well as in our case study (Fig. 4). The annular ligament is one of the deep plane origins of the supinator muscle [16]. For this reason, an entrapped supinator muscle on US was found in all cases in this study. An entrapped supinator muscle has been described as the 'hook sign' or the 'J sign' in previous reports [5,17]. Dohi et al.17] also reported that the sensitivity, specificity, and accuracy of the ultrasonographic diagnosis of pulled elbow were each 100% based on the *J*-sign. Furthermore, another interesting US finding was subsupinator effusion, located in the anterior part of the radial

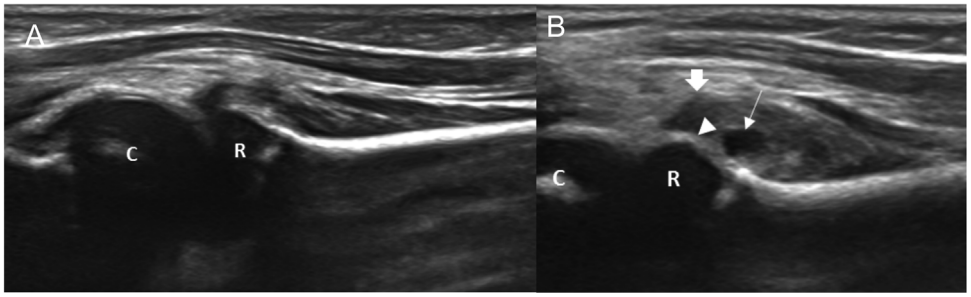

Fig. 3. In comparison with imaging before the reduction (A), ultrasonography after reduction (B) shows a disentangled swollen supinator muscle with a sharp edge (bold arrow), subsupinator effusion (arrow), and a restored annular ligament (arrow head). C: capitellum, R: radial head.

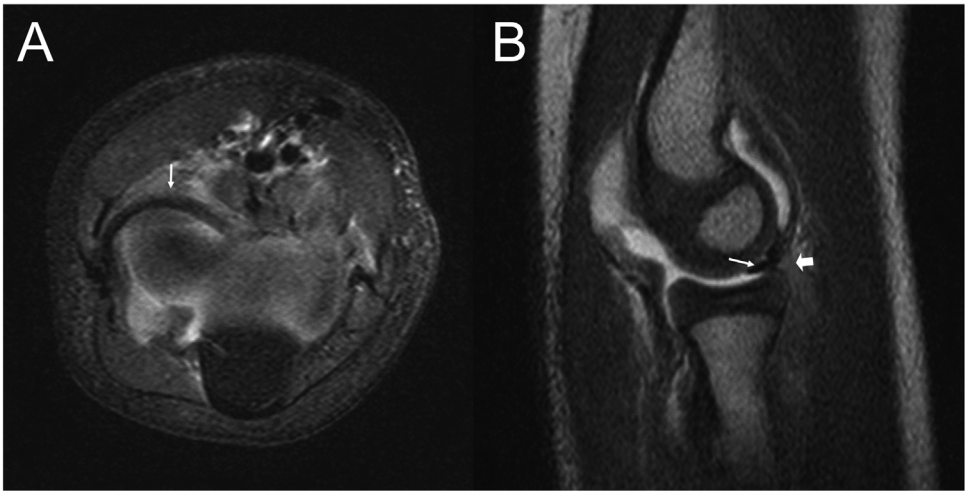

Fig. 4. Magnetic resonance imaging of a five-year-old boy shows the entrapment of the anterior part of the annular ligament between the subluxed radial head and the radiocapitellar joint (arrow on A and B) and an entrapped supinator muscle (bold arrow on B).

head, in 58% of cases after reduction. The location of subsupinator effusion was the anterior part of the radial neck, near the distal portion of the annular ligament. According to previous reports [18,19], the distal portion of the annular ligament attaches loosely to the neck via a synovial membrane, thereby allowing normal rotation during pronation and supination of the proximal radio-ulnar joint. Salter et al. [1] suggested that damage to this distal synovial membrane is often the first process to occur in pulled elbow. Therefore, we believe that subsupinator effusion might occur due to the flow of elbow joint fluid through the subannular ligament joint space around the radial head that accumulates in the damaged distal synovial membrane and supinator muscle.

Traditionally, in cases of pulled elbow, the posterior fat pad is not visualized on plain radiographs, and it has been considered a clue for occult nondisplaced fractures, in particular supracondylar fracture in children or radial head fracture [20]. However, in this study, a variable amount of elbow joint effusion at the olecranon fossa was found on US examination in most affected elbows. The annular ligament is not an isolated structure but a component of the lateral collateral ligament complex [15]. The lateral collateral ligament complex is a major lateral stabilizer of the elbow joint that resists varus stress. Furthermore, the annular ligament is not a uniform ligamentous band and can be variable in its morphology [21]. Indeed, Berg et al. [22] showed a variable synovial fold at the superior edge of the annular ligament extending into the radio-capitellar joint on histologic study. For these reasons, we speculate that when the superior annular ligament, which forms a tight ring around the radial head, is disrupted, the elbow synovium may become injured, resulting in elbow effusion. Mak et al. [15] also reported that elbow effusion was found in patients with a disrupted annular ligament caused by posterolateral elbow injury or pulled elbow. Owing to this elbow joint effusion, the posterior fat pad sign may be present on plain radiographs, which was observed in six of the 37 elbows (16%) in this study. Therefore, pulled elbow should be not excluded when the posterior fat pad sign is observed on plain radiography.

In this study, the success rate of reduction was 74% on the first attempt using the hyperpronation or supination-flexion maneuver. Bek et al. [23] reported an overall success rate of 97.5%, while McDonald et al. [24] achieved successful reduction on the first attempt in 100 out of 135 patients (74%). A click at the time of reduction may be considered indicative of a successful reduction. In a study of 2331 pulled elbows that developed over a 10-year period, a click was felt in 294 patients (55.5%) and splint application was not needed [12]. In the present study, although a click was not felt in three cases, the reduction was considered successful because the annular ligament was restored on US with free elbow motion. The reason for the absence of a palpable click in cases of successful reduction is not clear, though it may be due to local soft tissue swelling or a small hemorrhage in the region of the annular ligament. Therefore, US examination and inspection of the clinical improvement in elbow motion are critical for assessing the status after a reduction maneuver, even in the absence of a click.

In this study, four patients who had to undergo reduction under anesthesia had either a history of several episodes of pulled elbow or severe ligament laxity. Amir et al. [25] reported that the prevalence of hypermobility among children with pulled elbow was 73%, which is 23% higher than that in normal children of a similar age, and pulled elbow can be considered to be a consequence of joint hypermobility. Therefore, the physician should be aware that several reduction trials may fail in the context of severe ligament laxity. Furthermore, according to a previous report [4], it may be necessary to obtain an MRI for further evaluation in such cases, and other methods such as reduction under anesthesia or surgical reduction should be considered.

There are several limitations to our study. First, the number of patients with pulled elbow was insufficient to generalize the outcomes of this study. Second, our institution is a tertiary referral hospital; hence, our study subjects may have had more serious injuries compared to the average injuries in other hospitals and may not represent the general population with pulled elbow. Third, the controls were not recruited from a healthy population, and the extent of supinator muscle shape variation, synovial fringe, and amount of coronoid or olecranon effusion were unknown. However, to compensate for the individual variability, these pathognomic US findings in the affected pulled elbow were compared with those of the unaffected contralateral elbow. Furthermore, all US examinations were performed by a single experienced pediatric orthopedic surgeon so as to minimize the bias from inexperienced examiners and reduce interobserver error. Further prospective, controlled, randomized studies are necessary to determine the generalizability of the outcomes of this study and to analyze the factors associated with reduction failure.

Conclusions

In older children, pulled elbow can be caused by atypical mechanisms of injury such as slipping and rolling over the arm.

Clinicians should be aware of the possibility of the posterior fat pad sign on plain radiographs of pulled elbow in order to prevent unnecessary immobilization. In such atypical circumstances, US is a useful method for detecting an entrapped supinator and confirming adequate reduction via restoration of the annular ligament in children with atypical pulled elbow.

Conflicts of interest

All named authors have no conflicts of interest to declare.

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